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The performance of a white clover based dairy system in comparison with a grass/fertiliser-N system. II. Animal production, economics and environment

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Abstract

The performance of a white clover based dairy system in comparison with a grass/fertiliser-N system was studied during three years. Both systems had 59 cows, plus young stock, on an area of 40.6 ha for grass/clover and 34.4 ha for grass/fertiliser-N.

During the grazing season, the cows in both groups were supplemented with 3.5 kg concentrates day^{-1}. The daily Fat and Protein Corrected Milk (FPCM) production was 25.7 and 26.5 kg cow^{-1} for grass/fertiliser-N and grass/clover, respectively. The difference in milk production occurred from July onwards. Despite preventive measures in the grass/clover system, bloat occurred several times between August and October. During the housing season, cows received *ad libitum* grass or grass/clover silage with 6 kg concentrates cow^{-1} day^{-1}. Although the intake of grass/clover silage was consistently higher, there were no differences in milk production.

The grass/clover system had a lower N surplus, but this was related to the lower intensity of the system. The overall N utilisation was 25% in both systems. The average nitrate concentration in drain water, measured on a selection of fields, was 26 and 28 mg l^{-1} for grass/fertiliser-N and grass/clover, respectively. The nitrate concentrations in drain water from grass/clover fields were positively related with the clover content in the sward. The energy use of the grass/clover system was 15% lower than that of the grass/fertiliser-N system, with the fertiliser use as the main source of difference. Compared to the grass/fertiliser-N system, the gross margin per cow was slightly higher for grass/clover, but the gross margin per ha was 10% lower for grass/clover.

Considering agronomic and environmental aspects only, white clover based dairy systems are a viable option for the future, but from a financial viewpoint the use of white clover will be restricted to systems which produce approximately 12 t FPCM ha^{-1} year^{-1} or less.

Keywords: white clover, perennial ryegrass, dairy system, nitrogen, milk production, gross margin, energy

Introduction

In the Netherlands, developments such as the introduction of milk quota, concern about N losses (Aarts *et al.*, 1992) and growing interest in organic farming have reduced the use of fertiliser N since the early 1980's (Bussink & Oenema, 1998). Consequently, there is renewed interest in the use of mixed swards of perennial ryegrass and white clover.

Most experiments with grass/clover swards have considered only certain aspects like agronomic factors or animal nutrition factors, while only few experiments studied whole farm systems. In the Netherlands, system studies with grass/clover have been restricted to organic farms (Van der Meer & Baan Hofman, 1989) and integrated farms (Lantinga & Van Bruchem, 1998). In other countries in Northwest Europe, convential clover based farming types have been compared to fertiliser N based systems. Ryan (1989) reported a comparison of five grazing seasons between a grass/fertiliser-N system, stocked at 3.2 cows ha^{-1} and fertilised with 361 kg N ha^{-1} $year^{-1}$ and a grass/clover system, stocked at 2.52 cows ha^{-1} and fertilised with 122 kg N ha^{-1} $year^{-1}$. The milk production per cow was 6% higher, but the milk production per ha was 16% lower in the grass/clover system. Leach *et al.* (2000) presented whole-year comparisons between a grass/fertiliser-N system with 350 kg N ha^{-1} $year^{-1}$ and a grass/clover system with no fertiliser N. Initially, both systems had the same stocking rate of 1.9 cows ha^{-1} and the same target milk yield of 5700 l cow^{-1} $year^{-1}$. The target yields in the grass/clover system could only be realised with an additional input of approximately 300 kg concentrate cow^{-1} $year^{-1}$. In the third year, the stocking rate of the grass/clover system was reduced to 1.5 cows ha^{-1} and the target yields per cow could be achieved with similar concentrate inputs. However, the milk yield per ha was 21% lower in the grass/clover system. Weissbach & Ernst (1994) reported a six-year comparison between a grass/fertiliser-N system (392 kg N ha^{-1} $year^{-1}$) and a grass/clover system (44 kg N ha^{-1} $year^{-1}$). They also found similar milk yields per cow but a 40% lower milk yield per ha for the grass/clover system.

In the present experiment the performance of white clover was studied in a conventional Dutch dairy system, i.e. non-organic, alternating rotational grazing and cutting for silage and a high yielding dairy herd. The objectives were (i) to compare the agronomic, environmental and economic performance of a white clover-based dairy system with a moderately intensive grass/fertiliser-N system, (ii) to identify potential problems in the utilisation of white clover in dairying, and (iii) to design an agronomically, environmentally and economically sound white clover-based dairy system.

The first paper on this experiment (Schils *et al.*, 2000) described the botanical composition and sward utilisation in both systems. The average white clover ground cover was 31, 30 and 26% in the three subsequent years, but with a large variation between years, seasons and paddocks. Grass/clover and grass/fertiliser-N swards received 69 and 275 kg N ha^{-1} $year^{-1}$, respectively, including the inorganic N from cattle slurry. The average annual net dry matter yield on grass/fertiliser-N was 10.8 t ha^{-1} compared to 10.1 t ha^{-1} on grass/clover. The yield difference was smaller than expected, causing a silage surplus for grass/clover. The organic matter digestibility of grass/clover was marginally, but consistently, higher than that of grass-only, while the crude protein concentration was consistently higher from July onwards.

In this second paper the animal production data and overall system performance is presented

Materials and methods

Systems layout

The experiment consisted of a comparison between a grass/clover and grass/fertiliser-N dairy system (Table 1), conducted on the Waiboerhoeve experimental station at Lelystad, from May 1990 until April 1993. One farm manager ran both herds, which were housed under one roof, but in independent units with separated silage clamps and slurry storage facilities, cubicles, feeding passages and milk tanks. Further details about the history of the site, soil characteristics, weather data, the establishment of swards, grassland management and fertiliser policy are described in Schils *et al.* (2000).

The dairy herds consisted of Holstein-Friesian cows, calving from October to April. In 1989/1990, these cows produced 7297 kg milk cow^{-1} year^{-1} with 4.38% fat and 3.37% protein. Before the start of the experiment all cows were grouped into pairs of the same age, calving date, milk production and genetic potential and pairs were then randomly split between both systems. In spring, dairy cows were turned out as soon as there was enough grass to start grazing. A rotational grazing system was applied with planned grazing periods of two days by dairy cows, followed by two days by young stock together with dry cows. The first priority was to have enough herbage for grazing, while surplus herbage was cut for silage. During the first two to four weeks at the beginning and during the last weeks at the end of the grazing season, the herds grazed only grass or grass/clover during daytime and were housed at night, where they were supplemented with approximately 5 kg silage DM cow^{-1} day^{-1}. During the grazing season, cows were fed 1 to 6 kg concentrates cow^{-1} day^{-1} in the milking parlour, depending on the milk production level. Furthermore, in 1990 and 1991 the cows in the grass/clover system were supplemented daily with 1 kg of a concentrate containing 10 mg Centralene® kg^{-1}, a bloat preventing agent

Table 1. System layout of grass/clover and grass/fertiliser-N dairy systems.

	Grass/fertiliser-N	Grass/clover
Milk quota (kg)	450,000	450,000
Pasture area (ha)	34.4	40.6
Dairy cows	59	59
Stocking rate[1] (LU ha^{-1})	2.2	1.9
Milk (10^3 ton ha^{-1})	13.1	11.1
Nitrogen application[2] (kg ha^{-1})	300	< 100

[1] LU = Livestock Unit: 0–1 year = 0.3, 1–2 year = 0.6 and cow = 1.0

[2] including inorganic N from slurry

containing 60% polyoxypropylene and 40% polyoxyethylene. From 1992 onwards, the use of Centralene® in concentrates was no longer permitted and therefore, the proportion of unsaturated fat in concentrates was increased during the grazing season of 1992 by inclusion of toasted soybean (15%). This modified concentrate was fed to cows in the grass/clover system as well as the grass/fertiliser-N system. During the housing season, cows were on an *ad libitum* silage diet with supplementation of concentrates to a level of 1 to 12 kg cow^{-1} day^{-1}, depending on the level of milk production.

Measurements and data analysis

A farm management system was used to record the animal data, i.e. feed intake, milk production, milk sales, milk quality, animal weights, animal health and fertility.

Nitrogen fixation by white clover was estimated as follows. Data from herbage samples and the botanical composition observed on the grass/clover paddocks (Schils *et al.*, 2000) were used to predict the white clover content in the dry matter ($CL_{dm,t}$) on day i (day number after 1st of January) from the autumn white clover cover (CL_{cov}) as follows: $CL_{dm,i} = 0.39*CL_{cov} - 0.316*i + 0.0330*i^2 - 0.00000746*i^3 + 0.00283*CL_{cov}*i$ (R^2=75.9%). The net DM yield per ha was calculated from the silage yield and the number of grazing days. It was assumed that one grazing day equals a net DM yield of 14, 7 or 3.5 kg for dairy cows, heifers or calves, respectively (Hijink & Meijer, 1987; Anonymous, 1997b). The net DM yields and clover contents in the sward were combined to calculate the annual clover yield. With the assumption that each tonne of clover DM is equivalent to a N fixation of 54 kg/ha (Van der Meer & Baan Hofman 1989; Elgersma & Hassink, 1997) the total fixation was estimated.

From October to April, drain water was sampled once per week from a random selection of 10 grass/fertiliser-N paddocks and 14 grass/clover paddocks and analysed for NO_3^--N, using a Nitracheck reflectometer and Merckoquant test strips (Elles *et al.*, 1987; Berry & Thicoipe, 1993).

The energy use of both systems was calculated with the energy module of a farm budgeting program (Hageman & Mandersloot, 1995), in which the total energy use is derived by multiplying the amount of energy carriers, products and services with their respective energy contents.

Results

Milk production

During the grazing season, the cows in the two systems were supplemented with a similar average amount of concentrates, approximately 3.7 kg cow^{-1} day^{-1} (Table 2). The silage supplementation was higher in the grass/fertiliser-N system, due to occasional grass shortage from July onwards, as described earlier in Schils *et al.* (2000). On average, the cows in both herds produced 25 kg milk cow^{-1} day^{-1}. Generally, daily milk production decreased throughout the grazing season, from approximately 29 to 21 kg cow^{-1}, in line with the herd's calving patterns. Average daily milk produc-

Table 2. Daily concentrate and silage supplementation and milk production during the grazing season.

	Mean		Grass/Fertiliser-N			Grass/Clover			Grass/Fertiliser-N			Grass/Clover		
	Grass / Fertil-iser-N	Grass / Clover	'90/ '91	'91/ '92	'92/ '93	'90/ '91	'91/ '92	'92/ '93	Start-Jun	July-Aug	Sep-End	Start-Jun	July-Aug	Sep-End
Dairy cows	54	53	52	53	56	51	51	56	56	54	51	57	54	47
Concentrate (kg DM cow^{-1} day^{-1})	3.7	3.6	3.8	3.9	3.4	3.7	3.8	3.2	4.4	3.1	3.5	4.2	2.9	3.4
Silage (kg DM cow^{-1} day^{-1})	2.1	1.4	1.9	2.5	2.0	1.2	1.2	1.9	1.9	0.7	3.6	1.9	0	2.0
Milk (kg cow^{-1} day^{-1})	24.7	25.2	23.4	25.1	25.4	24.9	25.2	25.6	28.9	23.9	20.8	28.6	24.7	21.6
Fat (g kg^{-1})	4.27	4.36	4.33	4.31	4.22	4.28	4.32	4.45	4.18	4.12	4.55	4.26	4.19	4.68
Protein (g kg^{-1})	3.47	3.47	3.55	3.45	3.43	3.46	3.52	3.43	3.44	3.4	3.58	3.41	3.39	3.65
FPCM[1] (kg cow^{-1} day^{-1})	25.7	26.5	24.6	26.2	26.2	25.9	26.4	27.1	29.7	24.4	22.5	29.6	25.4	23.7

[1] Fat (4%) and Protein (3.32%) Corrected Milk production

tion and fat concentration were slightly higher in the grass/clover system than in the grass/fertiliser-N system, but these differences were not consistent throughout the years. However, average fat and protein corrected milk production (FPCM) on grass/clover was always equal to or higher than that on grass/fertiliser-N. Higher daily milk productions occurred mainly from July onwards, while higher fat concentrations occurred throughout the whole grazing season.

During the housing season, cows were supplemented with approximately 6 kg cow^{-1} day^{-1} (Table 3). Although the intake of grass/clover silage was almost 1 kg DM cow^{-1} day^{-1} higher than that of grass/fertiliser-N silage, the milk production in both systems was similar. The fat concentration of the milk was consequently higher in the grass/fertiliser-N system, and therefore FPCM was somewhat higher as well. With a similar milk protein production, the higher intake in combination with a higher N concentration resulted in a lower N utilisation in the grass/clover system.

The annual fat and protein corrected milk production (FPCM) was 8294 kg cow^{-1} in the grass/clover system and 8095 kg cow^{-1} in the grass/fertiliser-N system.

Animal fertility and health

There were no relevant differences in fertility parameters of the two herds. The average number of inseminations per conception was 1.8, with a score of 48% pregnancy to first serve and a final result of 83% pregnancy of all cows served. The calving index was 382 days and there were 74 days between calving and first serve.

In the grass/clover system bloat occurred each year, but with varying frequency. In the establishment year 1989, 25 cows had to be treated for bloat, of which two died. In 1990 and 1991, when the cows were supplemented with bloat preventing means through concentrates, 9 cows were treated. In 1992, when bloat prevention was implied through a higher proportion of unsaturated fat, 7 cows were treated. All incidences of bloat occurred during night-time between August and October.

Table 3. Daily feed intake and milk production during the housing season.

	Mean		Grass/Fertiliser-N			Grass/Clover		
	Grass / Fertil-iser-N	Grass / Clover	'90/ '91	'91/ '92	'92/ '93	'90/ '91	'91/ '92	'92/ '93
Dairy cows	45	47	42	44	50	44	45	52
Concentrate (kg DM cow^{-1} day^{-1})	6.1	5.8	5.9	5.8	6.7	5.3	5.5	6.6
Grass silage (kg DM cow^{-1} day^{-1})	13.5	14.4	14.8	13.0	12.7	15.5	14.7	13.1
Milk (kg cow^{-1} day-$^{-1}$)	26.0	25.9	26.8	24.8	26.3	26.0	25.6	26.2
Fat (g kg^{-1})	4.75	4.62	4.67	4.83	4.76	4.58	4.62	4.65
Protein (g kg^{-1})	3.47	3.45	3.46	3.55	3.43	3.43	3.46	3.46
FPCM (kg cow^{-1} day^{-1})	28.5	28.0	29.1	27.5	28.8	27.9	27.7	28.4
N utilisation[1] (%)	26.6	24.5	25.2	28.4	26.6	24.4	24.5	24.8

[1] (N in milk / N in feed) *100%

There were no significant differences in the incidence, i.e. number of treated animals divided by the total number of animals, of other illnesses between the two herds. The most important illnesses, averaged over both herds, were lameness, with an incidence of 70%, sole ulcer (36%), irregular heat (27%), hypocalcemia (27%) and mastitis (23%). The reasons for culling were mainly fertility (42%), udder (18%) and production (13%).

Nitrogen budget

The higher intensity of the grass/fertiliser-N system is reflected in the annual N budget (Table 4). The higher N input through concentrates and the higher N output through milk and meat are associated with its 15% higher stocking rate. Obviously, the most striking difference is the substitution of fertiliser-N in the grass/fertiliser-N system by biologically fixed N in the grass/clover system. The amount of fixed N was estimated at 170, 182 and 175 kg ha^{-1} year^{-1}, in the three consecutive years. In the grass/fertiliser-N system, there was a net N input through silage that had to be bought to compensate for shortages, while the grass/clover system had a net silage surplus, which was sold. In the three consecutive years, the balance for silage was –13, –26 and +2 t DM year^{-1} on grass/fertiliser-N, and –2, +27 and +63 t DM year^{-1} on grass/clover. In this region of the Netherlands the atmospheric deposition of NH_3-N is estimated at 35 kg N ha^{-1} year^{-1} (Anonymous, 1993). Other inputs consist of litter (1 kg ha^{-1} year^{-1}) and an estimated fixation by free living soil bacteria (4 kg ha^{-1} year^{-1}).

The N surplus was 41 kg ha^{-1} year^{-1} higher on grass/fertiliser-N than on grass/clover, which is again related to the higher stocking rate. In terms of N efficiency there was no difference between the systems. Approximately 25% of the N input was recovered in the N output.

The similar N efficiency is illustrated by the weekly nitrate concentrations in drain water (Figure 1). The overall average nitrate concentration from grass/fertiliser-N and grass/clover paddocks was 26 and 28 mg l^{-1}, respectively, but there was a consid-

Table 4. Average nitrogen budget of the grass/fertiliser-N and grass/clover system (kg N ha^{-1} year^{-1}).

	Grass/fertiliser-N	Grass/clover
Concentrates	76	65
Fertiliser	208	16
Fixation	0	176
Silage	9	–18
Deposition	35	35
Other	5	5
Total input	**333**	**279**
Milk	70	61
Cattle	10	8
Total output	**80**	**69**
Surplus	**253**	**212**

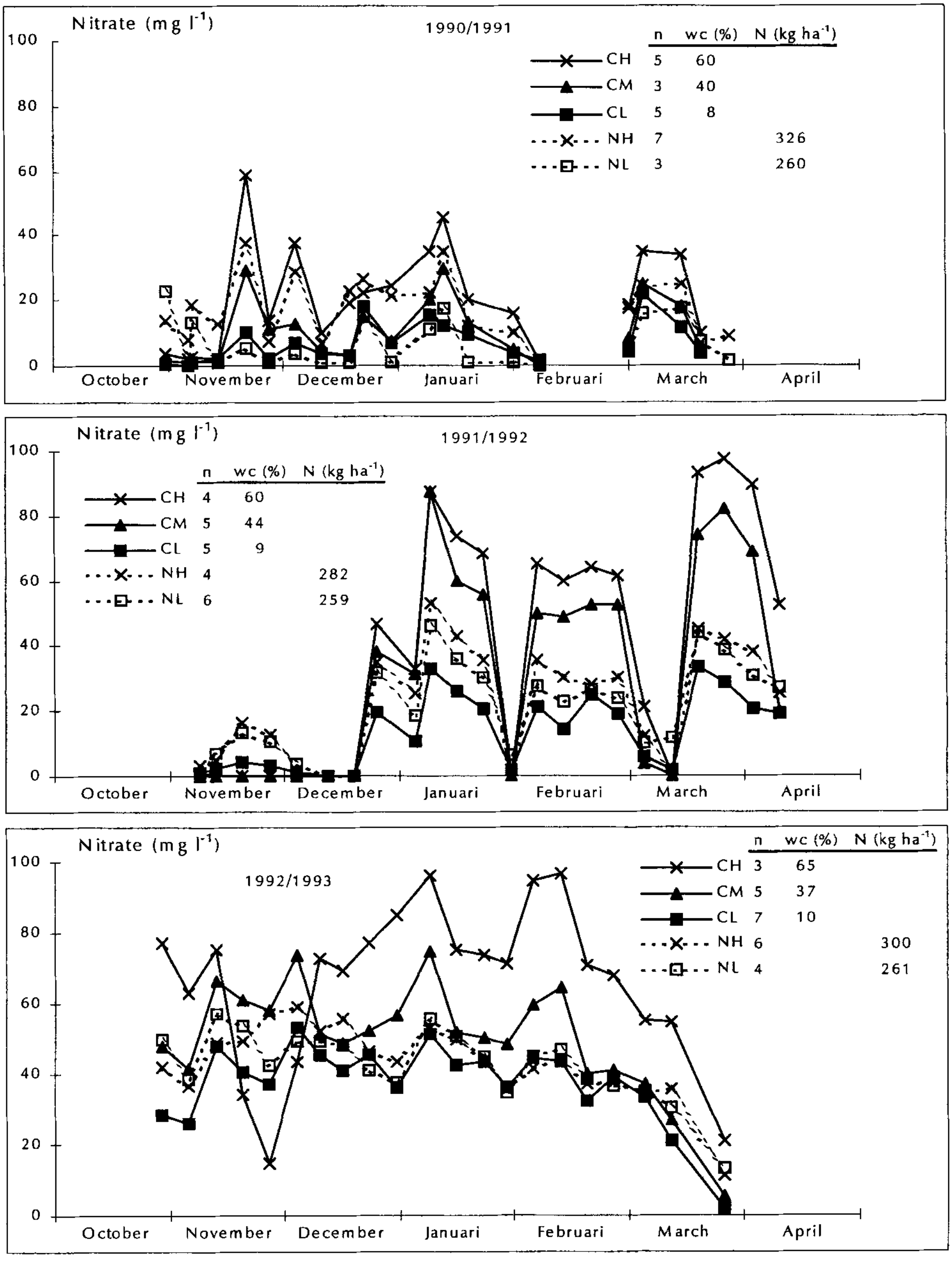

Figure 1. Average nitrate concentration in drain water (mg l^{-1}) in 1990/1991, 1991/1992 and 1992/1993, from grass/clover paddocks, in relation to white clover cover in the autumn, CL (< 20%), CM (20–50%) or CH (> 50%), and from grass/fertiliser-N paddocks, in relation to annual N application, NL (< 280 kg ha-1 year^{-1}) or NH (> 280 kg ha^{-1} year^{-1}). Number of paddocks (n), white clover content (wc) and N application (N) vary per year and are indicated in the legend.

erable variation between years, weeks and paddocks. The variation between paddocks could be partly explained by variation in annual N application on grass/fertiliser-N paddocks, and by variation in white clover cover on grass/clover paddocks. Each year, the nitrate concentration increased consistently with increasing white clover cover. For paddocks with an autumn clover cover of <20%, 20–50% and >50%, the average nitrate concentration was 20, 35 and 41 mg l^{-1}, respectively. The effect of N application on grass/fertiliser-N paddocks was clear in the first year, but not in the second and third year, in which years there was too little variation in N application rate between paddocks. For paddocks with an N application of < 280 and >280 kg ha^{-1} $year^{-1}$, the average nitrate concentration was 23 and 29 mg l^{-1}, respectively.

Energy use
The total energy use of the grass/clover system was 15% lower than that of the grass/fertiliser-N system, with the fertiliser energy use as the main difference (Table 5). In both systems, the indirect energy consumption through concentrates made the greatest contribution to the total energy consumption. The higher number of silage cuts in the grass/clover system gave a higher energy use through services, e.g. from contractors. The difference in silage shortage/surplus is included in other sources. The direct energy use was similar on both farms. The total energy use per 100 kg of milk was 440 and 374 MJ for grass/fertiliser-N and grass/clover, respectively.

Gross margin
Total revenues of the grass-clover farm were higher due to higher milk sales and the sale of the silage surplus (Table 6). The use of white clover reduced annual fertiliser costs to Euro 1,300 in the grass/clover system, compared to almost Euro 4,000 in the grass/fertiliser-N system. On the other hand, concentrate costs were higher, due to the use of Centralene® in 1990 and 1991. On the grass/fertiliser-N farm, silage had to be bought, at an average annual cost of nearly Euro 1,700.

The higher revenues and lower direct costs resulted in yearly advantage of Euro

Table 5. Average energy use of the grass/fertiliser-N and grass/clover system (GJ $year^{-1}$).

	Grass/fertiliser-N	Grass/clover
Diesel	124	122
Electricity	220	221
Direct energy	**344**	**343**
Concentrates	672	675
Fertiliser	286	37
Services	230	293
Buildings & Machinery	331	333
Other	100	16
Indirect energy	**1619**	**1354**
Total	**1963**	**1697**

Table 6. Average financial results of the grass/fertiliser-N and grass/clover system (10^3 Euro year^{-1}).

	Grass/fertiliser-N	Grass/clover
Milk	157.6	161.0
Cattle	20.1	19.6
Silage	0.0	4.0
Revenues	**177.7**	**184.6**
Fertiliser	4.0	1.3
Concentrates, milk replacer	17.7	19.3
Silage	1.7	0.0
Inseminations	1.5	1.6
Health	6.1	6.1
Interest	5.1	5.1
Other	1.1	1.1
Direct costs	**37.3**	**34.6**
Gross Margin	**140.4**	**150.0**
Gross Margin per ha	**4.1**	**3.7**

9,600 in the whole farm gross margin for the grass/clover system. The gross margin per cow on grass/fertiliser-N and grass/clover was Euro 2,405 and Euro 2,496 respectively. Although the grass/clover system was competitive to the grass/fertiliser-N system on the basis of a "whole farm" or "per cow" comparison, the higher stocking rate on the grass/fertiliser-N system shifted this to a clear advantage in terms of gross margin per ha, i.e. Euro 4,129 for grass/fertiliser-N and Euro 3,676 for grass/clover.

Discussion

Animal performance

There was no confirmation of a higher milk production with grass/clover, as reported in earlier feeding experiments with either silage (Castle *et al.*, 1983) or fresh herbage (Thomson *et al.*, 1985; Wilkins *et al.*, 1994; Remmelink, 2000). Considering that concentrate levels were similar in both systems and that a range of unintended and undetectable interactions may occur in system studies, the lack of a distinct response to clover is not surprising. Leach *et al.* (2000) and Weissbach & Ernst (1994) were also unable to demonstrate any milk production response to clover in their comparisons of grass/clover and grass/fertiliser-N based dairy systems.

Although the cows in the grass/clover system produced 1.1 kg FPCM day^{-1} more than the cows in the grass/fertiliser-N system, it is uncertain to what extent this difference can be attributed to white clover directly. It may be hypothesised that the higher stocking rate of the grass/fertiliser-N system is partly responsible for the silage shortage in that system. Along with the silage shortage, the area cut for silage, between July and the end of the growing season, was 40% lower in the grass/fertiliser-N system than in the grass/clover system. Consequently the mean proportion of grazing events on clean aftermath was 19% for grass/fertiliser-N and 37% for grass/clover.

There were no differences in milk production during the housing season, although the average silage intake was nearly 1 kg DM cow^{-1} day^{-1} higher for grass/clover. Possibly, the concentrate supplementation of 6 kg DM cow^{-1} day^{-1} has masked any effects of clover. Recent feeding experiments in the Netherlands (Remmelink, 2000) have confirmed that the milk production response to white clover is dependent on the concentrate level. Moreover, these experiments have revealed that the beneficial effect of white clover is higher in diets containing maize and grass(clover) silage together than in diets with only grass(clover).

The experiences in this experiment demonstrate that bloat is a potential hazard in rotational grazing systems with no supplementation of other roughages. The preventive measures used in this experiment, are either no longer allowed or unpractical for dairy farmers. Therefore it is advisable to prevent bloat by supplementation with small amounts of hay, grass silage or maize silage during periods with high risks. As experienced in a similar experiment in Scotland (Leach *et al.*, 2000), bloat risks might be lower in a set-stocking system, due to smaller and more gradual changes in the amounts of clover on offer.

Environmental performance

The achieved levels of N surplus and overall N utilisation do not suggest significant differences in the N utilisation between the two systems. Although the N surplus was 41 kg ha^{-1} year^{-1} lower in the grass/clover system, this is mainly a direct consequence of the lower stocking rate. The N surplus per kg N produced was only 3% lower in the grass/clover system. Furthermore the difference in silage surpluses distorts the comparison as well. The sale of silage from the grass/clover system reduced the N surplus and improved the N utilisation, since the production of forage has a much higher N utilisation than the transformation of forage into milk. On the contrary, the purchase of silage in the grass/fertiliser-N system for the production of milk increased the N surplus and reduced the N utilisation. The calculation of the N surplus in the grass/clover system is also affected by the uncertainty of the exact amount of biological N fixation. If the amount of biologically fixed N would be estimated 10% lower, then the N utilisation would increase from 24.7 to 26.4%. Weissbach & Ernst (1994) also indicated that the use of grass/clover swards in itself, being the substitution of industrially fixed N by biologically fixed N, would not improve the N utilisation as such. It is the extensification, i.e. switching from high fertiliser N input systems to lower fertilised N input or low input clover systems, that increases the N utilisation.

The nitrate concentrations, measured in the drain water, are in line with the finding that the N utilisation was similar in both systems. But they also show the risk of grass/clover mixtures when clover contents in the swards become too high. In this respect, the upper limit of 50% white clover in the sward, suggested by Pflimlin (1993), seems justified. Especially in systems with no supplementation of low protein forages the relatively high protein concentration of autumn grass/clover is a disadvantage. Therefore it is recommended to compensate the high amounts of protein ingested on clover-rich swards with supplementation of maize silage, which is widely grown in the Netherlands, or whole-crop cereal silage.

As stated earlier, the amount of N fixed by clover is based on several assumptions and therefore the calculated N surplus of the grass/clover system has to be treated with caution. Biologically fixed N does not have to be accounted for in the Dutch mineral accounting system (MINAS), as is also the case with atmospheric deposition (Anonymous, 1997a). Using the MINAS methodology, the N surpluses would be 214 kg ha^{-1} for the grass/fertiliser-N system and –3 kg ha^{-1} for the grass/clover system. It is evident from this study that the calculated N surplus in MINAS is not a good indicator for the environmental performance of clover based dairy systems. Farmers might for instance adopt so called two-sward systems, for example with 35% of the area in unfertilised grass/clover and 65% of the area with intensively fertilised grass-only swards. In this way they can comply with MINAS regulations, although the real N surplus might still be environmentally unacceptable.

An environmental benefit of the grass/clover system is the lower energy consumption and thus the lower claim on fossil energy reserves. The energy use per 100 kg milk in the grass/clover system, 374 MJ per 100 kg milk, is in the lower part of the range of 373 to 742 MJ per 100 kg milk, as found in studies by Hageman & Mandersloot (1995).

Financial performance

The gross margin per cow in the grass/clover system was about 6% higher than in the grass/fertiliser-N system. However, the gross margin per ha of the grass/clover system lagged some 10% behind that of the grass/fertiliser-N system. With current high land prices, farmers will try to maximise the milk production per ha within the environmental limits. The results of the present experiment showed that the white clover based swards were able to support a moderately intensive dairy system, producing approximately 12 t milk ha^{-1} $year^{-1}$.

Conclusions

A white clover based dairy system, receiving 69 kg inorganic N ha^{-1} $year^{-1}$, produced 85% of the milk yield per ha of a grass/fertiliser-N based system, receiving 275 kg inorganic N ha^{-1} $year^{-1}$. The N utilisation at farm level was nearly 25% in both systems, and there was no difference in the average nitrate concentrations in drain water. The total energy use of the clover based system was 15% lower than that of the fertiliser-N based system.

The agronomic and environmental performance show that white clover based dairy systems are a viable option for the future, but from a financial viewpoint the use of white clover will be restricted to systems which produce approximately 12 t FPCM ha^{-1} $year^{-1}$ or less.

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